present this member of the series is only seen as a number of isolated patches, and we have no evidence as to whether it ever constituted a continuous deposit. Its thickness is never great, and probably in no case exceeds 30 feet.

The "Cherty rock of Stotfield" which has afforded no traces of organic remains, even when studied under the microscope, is evidently a chemical and not an organic deposit. Its appearance and characters, indeed, strongly suggested that, like very similar deposits in Hungary, it may have been formed by geysers, an idea which was entertained by Sir Charles Lyell. If this be so, it is impossible to avoid entertaining the suggestion that the formation of the keys may have been due to the rise of heated water containing silica in solution along the joint planes of sandstones below. Some support is afforded to this suggestion by the fact that where, as at Stotfield, the Cherty rock is largely developed, there the quartzite "keys" are particularly numerous in the underlying sandstones.

It may be of some interest to add that the Trias of the district of Scania in Southern Sweden contains rocks quite undistinguishable in their mineral characters from the Pebbly Conglomerate, the Reptiliferous Sandstone, and the Cherty rock of the Trias of Eastern Scotland.

V. "Experimental Researches in Cerebral Physiology. II. On the Muscular Contractions which are evoked by Excitation of the Motor Tract." By V. A. Horsley, M.B., B.S., Professor Superintendent of the Brown Institution and Assistant Professor of Pathology in University College, London, and E. A. Schäfer, F.R.S., Jodrell Professor of Physiology in University College. Received December 1, 1885.

The following note gives the results of a large number of experiments which we have undertaken, in order to determine the character of the muscular contractions which result from excitation of the several parts of the motor tract, especially with reference to the rhythm with which the skeletal muscles respond to such excitation.

For the purpose of our experiments we may consider the motor tract under four heads, viz.:—1. Its commencement in the nerve-cells of the cerebral cortex. 2. The connexion of these cells with the lower nerve-centres by the nerve-fibres in the corona radiata. 3. Its continuation along the medulla oblongata and medulla spinalis (including the nerve-cells of those structures). 4. Its peripheral continuation along the motor nerves.

*Methods.*—Our method of proceeding has been to excite these several parts in succession, and record the contractions of one of the limb muscles upon a moving blackened surface, either by directly connecting the tendon with the lever of a myograph, or by Marey's method of transmission by tambours and indiarubber tubing, the time being simultaneously recorded upon the moving surface by a clock marking seconds. Usually the rate and duration of the excitation were also recorded by a small electromagnet. Besides the contractions resulting from electrical excitation, we have frequently obtained an accidental record upon the moving surface of spontaneous or voluntary contractions of the muscle the responses of which to electrical excitation of the cortex cerebri we were preparing to record, and we have thus been able to compare these records of voluntary contractions in animals both with the results of electrical excitation of the several parts of the motor tract in the same animals, and with records of voluntary contractions in the human subject. We have also studied in the same way the epileptoid contractions which are often found to follow a period of electrical excitation of the cortex cerebri in animals, and have compared these epileptoid contractions with numerous others recorded by one of us from cases of true epilepsy and other affections of the nervous system (in man and animals) accompanied by rhythmic muscular movements.

*Results.*—It was somewhat vaguely stated by Franck and Pitres,* and has generally been admitted by other authors, that so far as regards the rhythm of muscular response, the result of exciting either the cerebral cortex or any other part of the motor tract is precisely the same as that which is well known to be the case with the excitation of the motor nerve, namely, that for all rates of excitation the rhythm of muscular response is identical with the rhythm of excitation. Our experiments on the contrary show that this statement only holds good for low rates of excitation up to about ten or twelve per second, but that for all higher rates of excitation of the cortex cerebri, corona radiata, or medulla spinalis the muscular response does not vary with the rate of excitation, but maintains a constant rhythm which is independent of the excitation rate and approximates to ten per second.

The muscle-curves which we have obtained from different mammals as the result of successive excitation of the cortex cerebri, corona radiata after removal of the superjacent cortex, and of the cervical cord after section below the medulla oblongata, are very similar to one another, and exhibit along their course, both at the commencement and during the whole extent of contraction of the muscle, small but distinct undulations following one another at the rate of about ten

* "Travaux du Laboratoire de Marey," iv, 1879, pp. 412–447. See also a paper by the same author in the "Arch. de Physiologie," Nos. 1 and 2, 1885.

per second, with very considerable regularity, although in a few instances the rhythm may be a little slower or faster than these (eight to thirteen per second are the extreme variations recorded). These undulations have the same rhythm and character whatever the rate of excitation (unless this be allowed to fall below about ten per second). Moreover, precisely similar undulations are always visible upon the myographic curve of all voluntary or spontaneous contractions (including reflex contractions) both in the lower animals and in man.

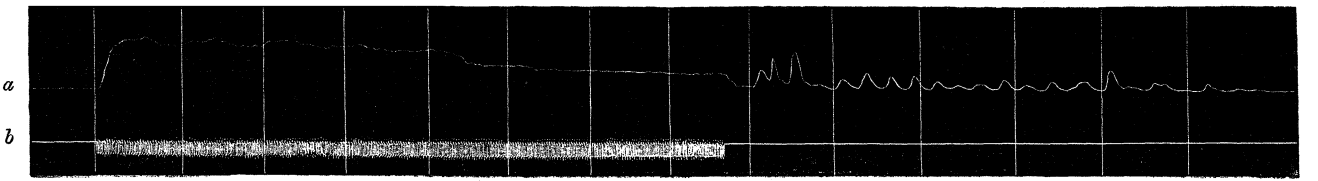
It is further noted that in the record of the contractions of epilepsy there can frequently be seen marked upon the larger curves, produced by the relatively slow clonic spasms, smaller undulations succeeding one another with a rhythm of eight or ten per second. In some cases the clonic contractions themselves may attain this rate, but they are then always simple and without any indications of smaller waves.

In a very few instances out of a very large number of experiments there occurred upon the tracings obtained as the result of rapid excitation of the cortex cerebri, corona radiata, and medulla spinalis, besides the usual well marked undulations of the rate of about ten per second, other very minute waves upon these undulations corresponding in rhythm with the rate of excitation. These were the only occasions in which we have obtained results at all similar to those mentioned by Franck and Pitres.

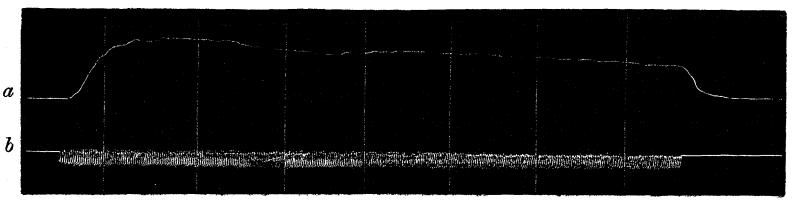
The accompanying tracings will serve to indicate the general nature of our results. Tracings A, B, C, and D are all taken from the same animal (dog). Tracing A shows the myographic curve obtained during excitation of the cortex cerebri (sigmoid gyrus), as well as the succeeding epilepsy. Tracing B was that obtained on excitation of the subjacent corona. Tracing C resulted from excitation of the cut spinal cord. Tracing D from excitation of the motor nerve. The excitation was produced by varying the current through the primary coil of a sliding inductorium by a metallic reed vibrating thirty times per second in the case of A, C, and D, and forty per second in the case of B. The vertical lines mark seconds. E is the tracing of a voluntary muscular contraction in man (opponens pollicis).

*Conclusions.*—The main conclusions to be drawn from the results of our experiments appear to be these:—1. That the normal rate of discharge of nervous impulses from the motor nerve-cells of the spinal cord along the motor nerve-fibres is approximately ten per second.* 2. That in the case of nervous impulses reaching these

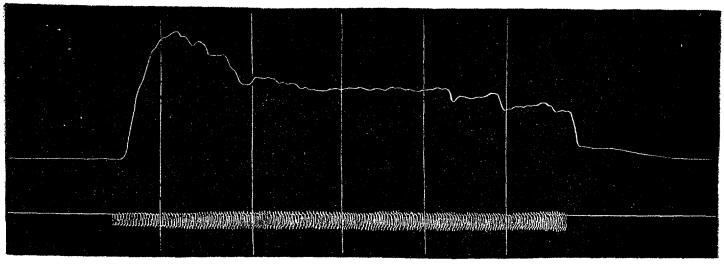
* This conclusion is supported by the fact that the rhythm of a clonus (*e.g.*, ankle-clonus) depending upon the activity of the spinal cord is also about 8 or 10 per second, and that the rhythm of strychnine-tetanus in the frog, as indicated by the electrical variations of the muscle-current, has about the same rate (Lovén).



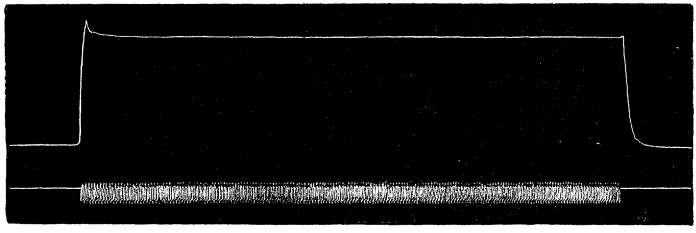

A. Tracing obtained from the extensor longus digitorum of the fore-arm of a dog as the result of rapid excitation of the cortex cerebri. *a*, myographic curve; *b*, chronograph record of the period and rate of excitation. The ordinates mark seconds.



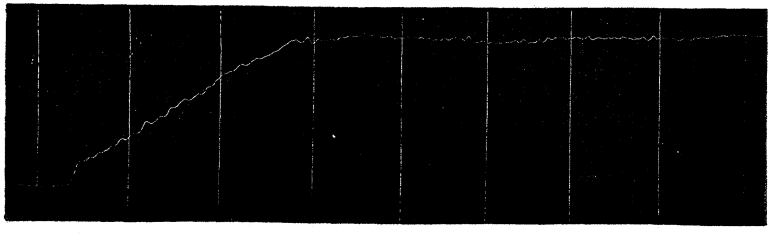

B. Tracing obtained as the result of excitation of the subjacent corona radiata after removal of the part of the cortex cerebri which was previously excited.



C. Tracing obtained from the same muscle as in A and B as the result of excitation of the distal end of the cut spinal cord.



D. Shows the result of rapid excitation of the motor nerve of the same muscle.



E. Tracing of a voluntary contraction of the opponens pollicis (man). The ordinates indicate seconds, as before.

nerve-cells in more rapid succession than about ten per second, a process of summation occurs within the nerve-cells, so that the rate of discharge remains about the same in all cases. 3. That the nervous impulses which produce a voluntary contraction also traverse the motor nerve-fibres at about the same rate. There is, however, no distinct evidence to show whether this rhythm of the volitional impulses is generated in the cells of the cerebral cortex, or in the cells of the lower nerve-centres. 4. That the slower rhythm which is often exhibited in epileptoid contractions is the result of a further summation, but there is no distinct evidence to show where this occurs.

5. That occasionally, though rarely, the summation of rapidly succeeding nervous impulses may be only incompletely effected within the nerve-cells of the spinal cord, or may not occur at all. In these cases results similar to those of Franck and Pitres are obtained.

A more detailed account of these experiments will shortly be published in the "Journal of Physiology."

*December* 17, 1885.

Professor G. G. STOKES, D.C.L., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

Professor Horace Lamb (elected 1884) was admitted into the Society.

The following Papers were read:—

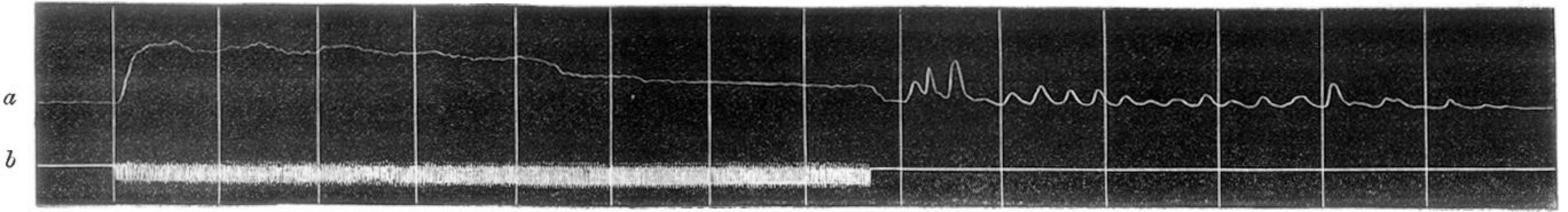
I. "An Experimental Investigation into the Form of the Wave Surface of Quartz." By JAMES C. MCCONNEL, B.A. Communicated by R. T. GLAZEBROOK, M.A., F.R.S. Received November 9, 1885.

(Abstract.)

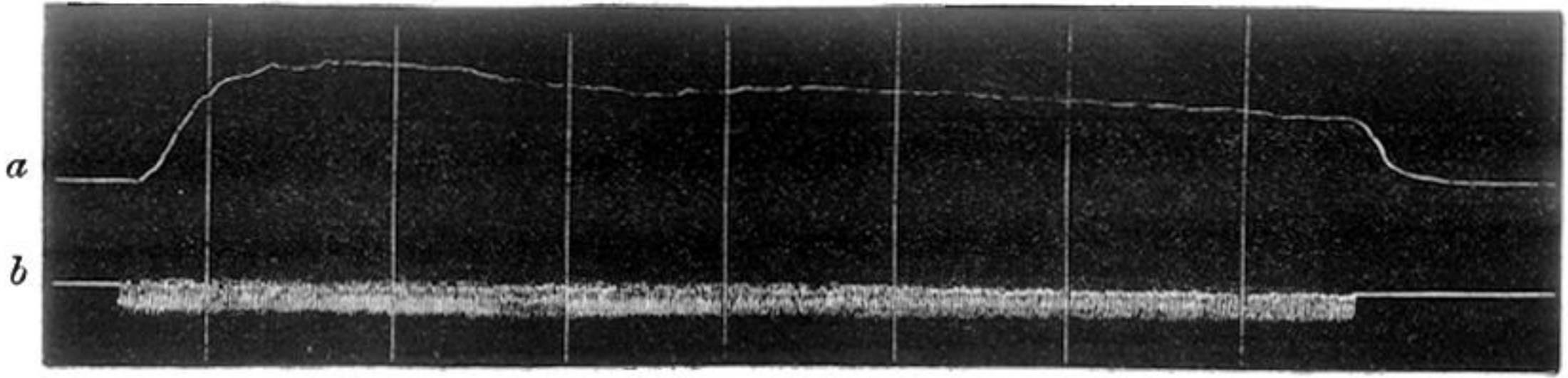
The paper contains an account of a number of measurements of the well-known "dark rings" of quartz. Each ring is due to one wave being retarded in the quartz behind the other by an integral number of wave-lengths, so the measurements give the directions through the plate of quartz corresponding to a series of known retardations. The relative retardation is, especially in a crystal of weak double-refracting power like quartz, mainly dependent on the distance between the two sheets of the wave surface. Thus my observations really give the separation between the two sheets at various points, and it is in this separation that the peculiarities of quartz are most strongly marked, and the various expressions put forward by theory most widely divergent.

With a plate cut at right angles to the axis, I obtained values of the separation from $\phi=4^\circ$ to $\phi=39^\circ$—$\phi$ being the angle between the ordinary wave normal and the axis—and with a plate cut parallel to the axis I obtained values from $\phi=53^\circ$ to $\phi=90^\circ$.

An obvious danger in this mode of investigating the wave surface




A. Tracing obtained from the extensor longus digitorum of the fore-arm of a dog as the result of rapid excitation of the cortex cerebri. *a*, myographic curve; *b*, chronograph record of the period and rate of excitation. The ordinates mark seconds.

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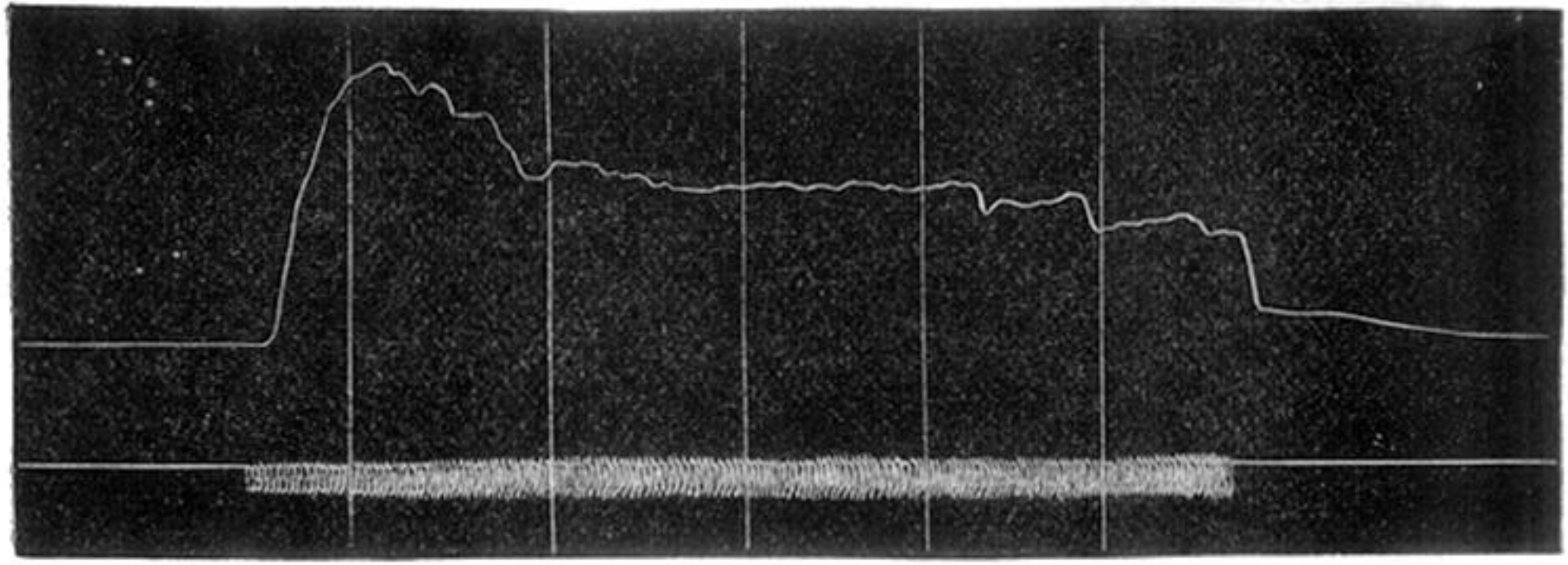
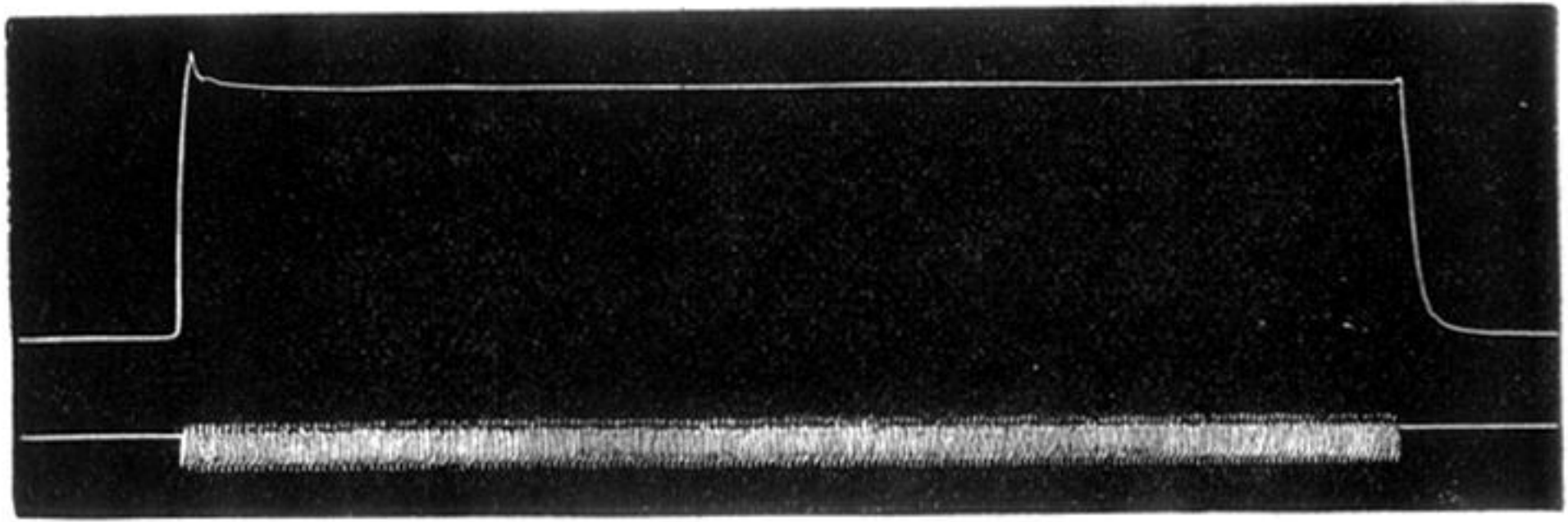


C. Tracing obtained from the same muscle as in A and B as the result of excitation of the distal end of the cut spinal cord.



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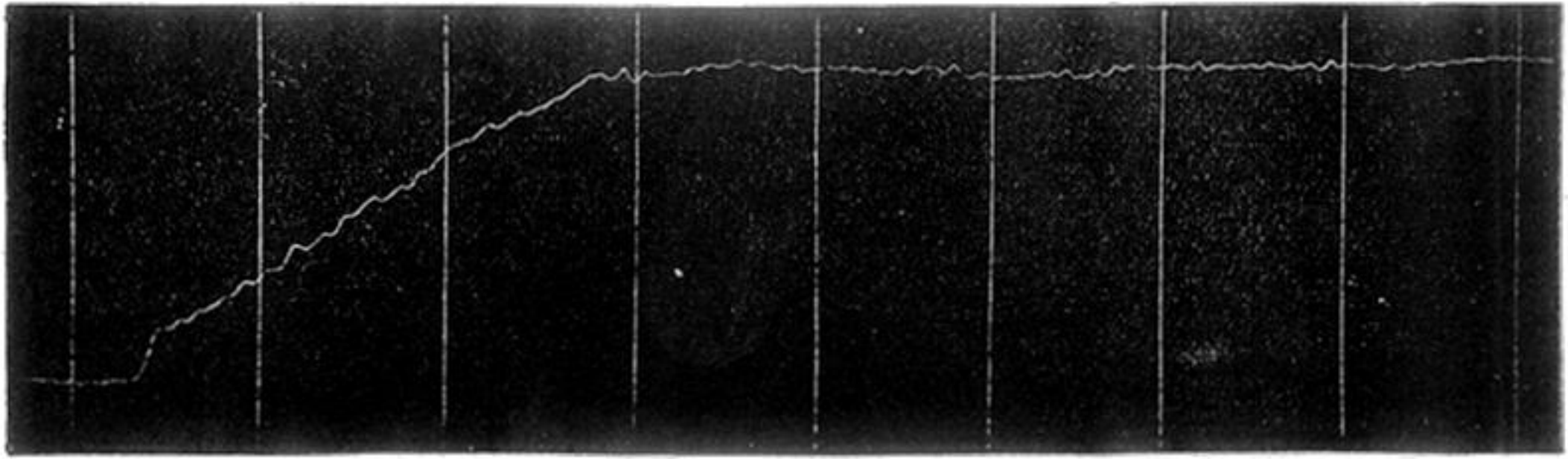

E. Tracing of a voluntary contraction of the opponens pollicis (man). The ordinates indicate seconds, as before.